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ENERGY AWARENESS

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FOREWORD

This television presentation of historical and geographical facts concerning the fossil fuel and natural gas energy supplies of the world, and the research and development programs of the U. S. Navy is an outgrowth of a television presentation first offered to midshipmen of the U. S. Naval Academy in 1978. Tailored to provide a broader appreciation of world-wide energy sources and logistics for the non-engineering majors, it is equally appropriate for the engineering majors as an adjunct to their studies of thermodynamics and vehicle propulsion systems.

The presentation starts with a short historical review of energy use patterns in the U. S. is given and leads into a discussion of present-day known supplies of various energy kinds, their geographical locations, and their present and projected price scenarios is presented. To this is added the U. S. Navy's requirements in both energy quantities and energy finances, with the result that the need for an effective energy research and development program becomes strongly evident.

Discussion of the Navy's Energy Research and Development Program starts with program structure and then moves through applications to ships, aircraft, facilities and mobility fuels. The presentation terminates with six pertinent conclusions.

ENERGY AWARENESS

Introduction

Energy awareness today involves understanding three critical facts: 1) the United States has a severe energy problem, 2) conservation of energy can have a tremendously positive impact, but it is not the entire answer, and 3) alternative sources of energy must be explored and developed.

During the last decade the nation suffered through an oil embargo, the Iranian revolution, two particularly severe winters and a major coal strike. The impact of these events was tremendous for many segments of our society. Schools and factories were forced to close, gasoline and heating oil became scarce and consumer fuel prices skyrocketed. Because the energy problem has so many facets we will focus primarily on those relating to the Navy.

Historical Review

Proj#1 Comprehension of the current U. S. energy problem becomes clearer when one realizes that in the past 60 years coal and the fluid hydrocarbons have essentially reversed positions in supplying their shares of the overall energy mix for the country. In 1920 coal supplied 78 percent of the nation's energy while petroleum and natural gas supplied only 18 percent. By 1982 coal use had dropped to 29 percent, petroleum use was at 29 percent and natural

gas had a 32 percent share. A shift of this magnitude in the sources of the nation's basic energy supply is understandable, because coal is difficult to extract and burn while oil and gas are much simpler to handle. As a result, the nation found itself operating on an economy geared to relatively cheap oil and natural gas, even though potential U. S. coal reserves are far greater than oil. The roughly four-fold jump in world oil price in 1973, plus the fact that U. S. domestic crude oil production actually peaked about 1973, created a
Proj#2 bleak picture, economically and otherwise, for a nation that would soon be forced to import more crude oil than it produced.

What about the conservation of energy? Experience during the 1973 oil embargo pointed up the tremendous effectiveness of an all-out energy conservation program. However, projections of future
Proj#3 energy consumption trends indicate clearly that energy conservation alone will not solve the problem. Society, having geared its economy to relatively cheap oil and natural gas, must now struggle to realign its requirements with prices approximately ten times the pre-1973 amount. A change in our basic lifestyle may be necessary for conservation efforts to be effective.

Looking toward the future let's recognize an already defined
Proj#4 sequence of time periods. Near-term is used to denote that segment of time from the present to 1985, mid-term from 1985 to 2000, and far-term beyond the year 2000. Very few options remain for improving the near-term energy development picture. In the mid-term, the

nation will continue to rely on foreign oil, its own declining production of gas and oil, conservation, and development of alternate sources. In the far-term new developments such as fusion and magneto-hydrodynamics show much promise, but problems associated with their development are complex and need clear and concise national policies and priorities before substantial advancement toward their realization may be expected.

Proj#5 This is a view of actual national energy consumption by end-use sector from 1973 to 1982. The residential/commercial sector indicates a fairly constant requirement of about 25 Quads, the transportation sector shows a fairly constant requirement of about 20 Quads, while the industrial sector shows a substantial reduction around 1975 and an expansion around 1979. From 1979 on, the industrial sector shows a decline from 32 to about 26 Quads (one Quad = 10^{15} Btu - 1 barrel average imported crude oil = 5.89×10^{6} Btu). In terms of total energy, the industrial decline from 1979 to 1982 equates to a drop from 44 percent to 35 percent, while percentages for the combined residential/commercial and transportation sectors are 33 percent and 26 percent respectively.

Proj#6 An interesting and important facet of transportation energy requirements is shown here in a comparison of the major modes of commercial transport. Water and rail transportation are, by far, the most economical on a Btu/ton-mile basis, while pipeline, truck and air transport are shown as far less effective. The automobile, with

its driver as single occupant, depicts a most questionable, and perhaps indefensible, position in the energy efficiency category.

Proj#7 Here you see how the United States became vulnerable to oil imports. If we look back to the period 1950 through 1955, domestic production and supply of petroleum products were keeping pace with the domestic demand. From 1955 to 1960 domestic production leveled off, and in 1960, began to rise again at a rate consistent with the domestic demand. But, from 1968 to 1972, again there was a leveling off and, in fact, domestic production of petroleum products in the United States peaked at about 1973 and started to decline from then until 1976 and is continuing down today. Looking at total domestic demand and its continuous rise from 1965 to 1973, the time of the oil embargo, we can see how the demand rose while the domestic supply leveled off and put us in the vulnerable spot in which we find ourselves at the present time.

Proj#8 This depicts the world proved reserves of crude oil in percent of total, including the 1977 discovery of huge quantities of both oil and natural gas in Mexico. Distortion of the map is in keeping with the relative percentages of total crude oil represented by each area. Perhaps of greatest significance here is that Mexico's percentage of crude oil now matches that of the Arab Middle East, the former leader. The U. S. is shown having one-tenth the crude oil of Mexico or the Arab Middle East.

Proj#9 In world reserves of natural gas, the U.S.S.R. leads in quantity with 27.9%, Iran is second with 22.5% and the United States is third

with just under 10%. North Africa and the Middle East are just about equivalent to the United States in Natural Gas Reserves. In Barrels of Oil Equivalent, the ratio for crude oil to Natural Gas Reserves is approximately 2.5 to 1.0.

Proj#10 Another source of world petroleum is oil shale. Here the United States stands in a dominant world position regarding supply with about 85%, while its next closest competitors are Canada with 7.0% and the Peoples Republic of China with 6%. At 2,620 Billion Barrels of Oil Equivalent, oil shale represents about one fifth the total supply of fossil fuel in the world. Unfortunately, what oil shale adds to the total energy picture in quantity, it loses in difficulty of processing and cost.

Proj#11 World fossil fuel deposits are shown here in per cent of total where the constituents are oil, natural gas, coal, oil shale and tar sands. The United States dominates the picture with 32%, its next closest competitor is South America with 16% and third is the Soviet Union with 11.6%. Coal, with the United States having almost half the world's known supply, and oil shale at an 85% share of known world supply are heavily responsible for the U.S.A.'s creditable showing among fossil fuel suppliers. It is interesting to note that the known aggregate world fossil energy supply equates to 12,540 Billion Barrels of Oil.

Proj#12 In the 20 year time span between 1960 and 1980 Navy fuel price, in constant 1981 dollars per barrel, showed this variation. Even

without the time scale on the abscissa, the effect of the 1973 oil embargo and the 1978-1979 Iranian revolution are easily identifiable. The price used here is an average price of the Navy's JP-5 and Diesel Fuel Marine.

Proj#13 Events such as the embargo and the revolution make prediction of future petroleum fuel prices very difficult, particularly when considering all the additional variables involved.

Accordingly, this projection shows four possible variations for Navy fuel prices, at zero, two, five, and ten percent rates of annual inflation. While it might be argued that the ten percent rate is unrealistically high, the equivalent annual rate from 1960 to 1981 was eight percent and from 1973 to 1981 was 23 percent.

Navy Energy Requirements

Now, how does the Navy fit into this energy picture of supply, demand and uncertain future price? The Department of Defense is our

Proj#14 Government's largest energy consumer and in 1981 consumed two percent of total U.S. energy. The quantities in MBOE (Millions of Barrels of Oil Equivalent) and the BTU equivalent for one barrel of oil and one Quad are indicated at the bottom of the picture. As such a large individual user of energy, the DOD is vitally concerned with foreign oil imports, the impact of oil embargoes and price increases on armed forces operating costs and the severe national security problems that any or all of these conditions might generate. While other sectors

of the economy have the option of using any of several energy sources, transportation and defense are severely limited in such alternatives. In the Navy's case, except for nuclear powered major combatant ships and submarines, all other ships, aircraft and small craft will require liquid hydrocarbon fuels in the foreseeable future. Therefore, any economic, political, or other action, national or international, which affects either energy supply or distribution, will have its concomitant effect on fulfillment of the Navy's mission.

Proj#15 Here is the fiscal year 1981 Department of Defense petroleum energy demand. The division among the Services is shown, Air Force 52.6%, Navy 35.4%, Army 9.4% and the Marines 2.6%. In Fiscal year
Proj#16 1980 the total energy demand for the Navy was 81.5 million barrels of oil equivalent and the petroleum energy demand was 57.8 million barrels of oil equivalent. Of significance here is the approximately 15 per cent reduction in Naval petroleum demand between FY 75 and FY 80, and the approximately 6% drop in total energy demand in the same time period, based on the fiscal year 1975 quantities. Cold iron refers to the shore-to-ship power supplied when the ship's steam and electric plants are not in operation. Ships and aircraft, as expected, show little variation in this comparison pointing up their almost complete dependence on petroleum energy.

Proj#17 Another way of showing the various Navy demands for total energy and their 1975 and 1981 comparative values is this bar chart. The only 1981 increase shown, of course, is in cold iron energy.

Proj#18 A natural follow-up to the 1975-1981 energy use chart is a comparison of actual or predicted energy use plotted alongside the corresponding cost. Here are actual and predicted values for the decade 1975-1985. The Navy's operating tempo determines, to a great degree, its total energy use, while national and international political and economic factors determine the energy cost.

Proj#19 Another and more startling indication of cost variation over the last few years is this depiction of petroleum cost variation between the years 1975 and 1981.

Proj#20 Putting all these energy requirements and costs together, and viewing them over the quarter-century 1975-2000 produces a Navy energy picture like this. Total energy requirements are shown by the top curve and that total is divided for ships, shore, and aircraft requirements on the lower three curves. Changes in these curves are caused by adjustments in optempo, the addition of new construction ships to the fleet, increased use of cold iron and simulators, hull cleaning and jet plans. Figures on the right side of the graph show the 1976 total energy cost as 1.2 billion dollars while the year 2000 energy cost, still figured in 1976 dollars, would be 2.8 billion dollars. That increase of roughly two and one-half times is significant.

Navy Energy R&D Program Structure

Proj#21 In order to manage properly the many-faceted Navy energy problem, an Energy Research and Development Program has been

established with the two-fold objectives: (1) to improve Navy energy efficiency, and (2) to develop a wider variety of energy sources. The technical thrusts for these objectives are (1) conservation applied to ships, aircraft and facilities, (2) develop strategies

Proj#22 which permit use of a wider variety of mobility fuels for ships and aircraft, and (3) substitution of alternate fuels at Navy facilities. A more detailed view of the project areas along with operational goals and a suggested time frame for these goals is shown here. Desired savings of energy in millions of barrels of oil equivalent are listed on the right for both FY 1985 and FY 2000 with sub-totals shown for ships, facilities and aircraft.

Ships

Proj#23 Starting with the Navy Shipboard conservation research and development program, a 20 percent fuel savings is sought through machinery system optimization, advanced hull cleaning methods and new anti-fouling hull coatings. The expected payoff is increased range and performance as well as substantial fuel and cost savings.

Proj#24 This shows examples of hull cleaning devices and methods, application of anti-fouling paints and a comparison of two pieces of metal with different organo-metallic paints after five years' exposure to a normal ocean environment. The heavy surrounding fouling is untreated metal with the same exposure.

Proj#25&26 Here is an enlarged view of one of the hull cleaning devices along with its method of application.

Proj#27 Fleet energy conservation projects which have already been put into effect are shown here, all of which show considerable promise. New thrusts among these projects are the oxygen content stack gas analyzer, the newly designed low-excess air burner and a more efficient economizer. Machinery procedural improvements, while not new, are such that they can save substantial quantities of energy. For instance, less standby reserve in turbo-generator and main feed pump capacity, and closer monitoring of combustion excess air.

Proj#28 Power plant efficiency improvements are many and varied. They apply to steam boilers and their propulsion systems, gas turbine propulsion systems and Diesel engines which are returning to prominence in both the non-combatant propulsion field and the electric
Proj#29 generating field. The reason for turning to the Diesel engine in these two fields is its excellent thermal efficiency across a broad range of power demands. This comparison of thermal efficiencies versus brake horsepower output for modern high, medium, and low speed Diesel engines with the LM2500 gas turbine and the current 1200 psi steam plant tells a large part of the story.

Proj#30 Another way of comparing ship propulsion plants is shown here, plotting specific fuel consumption in pounds of fuel per brake horsepower-hour against ship speed. The characteristics of the gas turbine plants may be compared with the 1200 psi steam plant at various speeds and against a destroyer-type ship speed-time profile.

Proj#31 Combined power plant systems offer opportunities for greater shaft power output as well as higher thermal efficiencies than either

of the separate systems operating alone. Here is a Rankine cycle with an organic fluid using the exhaust energy of a Diesel cycle to improve generator output by about 10 percent. The organic fluid is chosen such that its physical and thermal properties match the requirements as set by the Diesel engine exhaust. This is an

Proj#32 equipment schematic for the organic Rankine bottoming cycle just shown, indicating the relative locations of turbine, condenser, vapor generator and pump.

Aircraft

Proj#33 Aviation conservation projects in the Navy Energy Research and Development Program divide naturally into procedural measures and hardware applications. In the procedural projects, analyses of energy requirements for various duty cycles and flight scenarios lead to the most energy efficient methods and schedules for both in-flight and ground operations. In the hardware category, airframes and propulsion efficiency studies lead to optimum designs for specific

Proj#34 aircraft missions. Various options for both ground and flight operations are frequently available and it is essential that the most efficient of these options be used in every case. One recent study determined that considerable aircraft fuel could be saved by moving a refueling truck to an aircraft to be fueled rather than taxiing the aircraft to the truck location. It's a simple idea that works.

Proj#35 Another energy saving device is computer-optimized flight plans. Both for initial flight plans and for in-flight adjustments, the most

efficient conditions can be determined quickly and effected immediately to accommodate environmental or strategic changes involving a specific flight.

Facilities

Proj#36 Moving now to consideration of Navy Shore Facilities Energy Conservation, the major thrust is in Advanced Building Design Technologies and Application of Updated Design Criteria. The objective is to realize a significant reduction in energy requirement for a minimal monetary investment. Shore facilities are the most appropriate locations for Naval application of alternative energy
Proj#37 sources and the possibilities for these alternate sources are as shown. Coal can be used in almost any shore facility but presents problems of transportation, handling, storage and air pollution. Coal-water mixtures hold promise for overcoming many of these
Proj#38 problems. All the other alternate sources have certain geographical or demographical constraints that enter strongly into their feasibility. This view depicts certain of the alternate energy sources as
Proj#39 they are actually employed at selected naval bases. This next picture shows design applications used to reduce facility power requirements including energy monitoring and control systems that are already in use in some locations and are proving invaluable in cutting energy costs. Even though these systems are relatively expensive, some are paying back their initial costs in less than two years.

Proj#40 Geothermal energy is strictly limited, geographically, but the Navy is fortunate to have copious quantities available at one of its facilities. Potential Navy sites for geothermal energy are shown

Proj#41 here, and COSO is the location of considerable promise. While its ultimate capacity is still not known, some sources indicate it may be

Proj#42 able to generate electrical energy equivalent to the requirements of all West Coast naval bases. This is an actual view of the Navy's geothermal energy site at China Lake during the drilling operation.

Mobility Fuels

Proj#43 As indicated earlier, for a considerable period into the future, non-nuclear ships, small craft and aircraft, as well as ground support vehicles, will be operating on liquid hydrocarbon fuels as their mobility fuel. This generates the need for a specific mobility fuels research and development program to reassess fuel procurement specifications, develop fuel qualification procedures, qualify synthetic

Proj#44 fuels and monitor the health, safety and logistics aspects of mobility fuels. The results expected are maintenance of performance standards with poorer quality fuels, reducing fuel costs, increasing

Proj#45 fuel availability and improving qualification standards for fuels. Lower quality crude petroleum requires additional processing to bring

Proj#46 it into conformance with specifications and different quality crudes come from different sources. This picture and the next one indicate a processing hierarchy both in terms of crude source and product cost.

Proj#47 Fuel quality may be evaluated in terms of a number of criteria, one of which is hydrogen content. This table showing mass percentages of hydrogen in various available crudes alludes to relative heating values of final gas turbine fuels refined from each crude, and also indicates contaminants which can be deleterious either to gas turbine engine components or the environment, or both. Fuel quality problems of corrosion and erosion again are functions of the

Proj#48 fuel constituents. Any of the substances shown under fuel properties not only affects the performance of the fuel in combustion, but also may wreak havoc on a whole list of engine components coming in con-

Proj#49 tact either with the fuel itself or its combustion products. Fuel quality problems originating primarily with combustion can be traced to hydrogen content, net heat of combustion, smoke point and, again, the olefins and the aromatics of the hydrocarbon chain. Affected members are all components exposed to the combustion process. Since

Proj#50 some Navy propulsion systems perform in hostile environments, fuel quality can and does generate problems in fluid flow. The fuel properties most closely aligned with these problems are shown, and the problems arising affect storage tanks, distribution lines, filters and pumps.

Proj#51 Flammability of fuels is an important property both from an operational and a logistics standpoint. Explosiveness deals not only with how a fuel performs its primary duty, but also with safety in handling and storage. Flash point determines the temperature at which thermally derived vapors emanate in such a way that they may be ignited by either a spark or an open flame.

Proj#52 Fuel storage can become a serious problem with fuels that contain or have a tendency to generate gum when allowed to remain static for any length of time. Storage tanks, pumps and supply lines, filters and coalescers experience all sorts of flow (or non-flow) problems with these unstable fuels.

Proj#53 Lubricity, as its name implies, signifies a fuel's ability to lubricate the devices and systems through which it flows. Naturally occurring compounds, sulphur-containing or oxygenated, may be removed during the refining process and have to be replaced with long chain fatty acids which form a mono-layer on opposing metal surfaces. Fuel pumps, fuel controls and other moving devices in fuel systems can stick or become scarred by a fuel whose lubricity is too low.

Conclusions

Proj#54 Now let's determine what conclusions can be drawn from these considerations:

1) The energy crises of the last decade have posed problems which will remain through the foreseeable future.

2) Higher petroleum prices will force all energy costs higher for the foreseeable future.

3) There is a need to apply alternate and substitute energy sources to shore based power plants and facilities until renewable energy sources and far-term new energy sources can be developed.

4) Changes in fuel properties necessitate development of qualification procedures based on current equipment requirements. Future hardware will be designed to operate on forecast fuel properties.

5) A strong mobility fuels research and development program is required to develop the technology and data base necessary to allow definition of Navy fuel-use strategies, both current and future, for petroleum and synthetic fuels.

6) A steady, concerted effort by all hands is mandatory to make energy conservation work to its maximum potentiality in all our mobile and shore facilities, and to produce the alternative energy sources the Navy requires to carry out its mission.